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The use of remote active deflectors for feeding u.h.f. relay stations

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Summary

The role of active deflectors in providing programme feeds to u.h.f. television relay stations is discussed. Particular attention is given to the provision of power supplies at sites remote from mains electricity supplies.

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1. Introduction

A u.h.f. television relay station usually gets its programme feeds off-air from another station, translates to a different channel group, amplifies and re-radiates the signals. An active deflector, however, amplifies but does not translate, so that radiation is on the same channels as those used for reception. In a few instances active deflectors have been used for direct service but they are successful only where the desired service area is compact and well isolated and the topography is such that the signal from the parent station is greatly attenuated. These constraints do not apply if the active deflector is merely used to provide a link to a conventional relay station that cannot pick up the parent station directly. There are, however, severe limitations of cost and there may be difficulties in providing power supplies. These aspects are discussed in the following sections.

2. Basic Requirements

A schematic of an active deflector is shown in Fig.1 together with the basic parameters defined in decibel units. (Corresponding lower case letters are used in the following to denote the actual parameters).

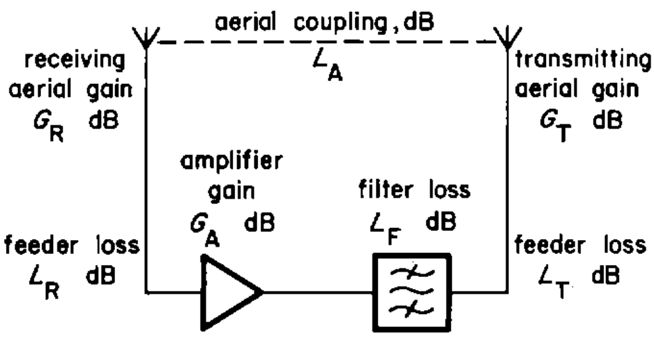

Fig. 1 — Schematic of active deflector

Let the field of the parent station be e volts/m or E dB(μV/m). The e.m.f. induced in the receiving aerial of power gain g_r is

$$e\lambda\sqrt{g_r}/\pi$$

and the power delivered to a matched load R_o is

$$g_r\, e^2\lambda^2/4\pi^2\, R_o$$

The power reaching the transmitting aerial is

$$g_a\, g_r\, e^2\lambda^2/4\pi^2\, R_o\, l_r\, l_f\, l_t$$

and the effective radiated power W_t is

$$g_t\, g_a\, g_r\; e^2\lambda^2/4\pi^2\, R_o\, l_r\, l_f\, l_t \; \ldots\ldots\ldots \quad (1)$$

This may be expressed numerically

$$Wt = E + 20\log_{10}\lambda + G_R + G_A + G_T - L_R - L_F - L_T - 123 \text{ dB(mW)} \ldots\ldots\ldots\ldots (2)$$

where $G_R = 10\log_{10}\ g_r$ etc.

and $L_R = 10\log_{10}\ l_r$ etc.

This quantity in turn may be used to establish how far the active deflector may be sited from the relay station, or, for a given spacing, to establish the amplifier gain required.

There is a further important consideration, namely that the gain in the loop formed by feedback between the aerials shall be less than unity at all frequencies, i.e. the system should not oscillate at any frequency.

$$\text{Thus } G_A < L_A + L_R + L_F + L_T \ldots\ldots\ldots\ldots (3)$$

This means that the coupling loss L_A between the two aerials should be high over the working frequency band and that the filter should attenuate all other frequencies at which the amplifier has positive gain and at which the aerial directivity may be poor.

3. Use of Commercial Equipment

Wherever a relay station serves only a small number of viewers, there must be severe restrictions on its cost. This is particularly so if an additional site is required to provide a programme feed. The cheapest equipment is that commercially available for other applications and the options available are here discussed in detail.

3.1. Amplifiers

There are several amplifiers available that are intended for cable distribution. Some are narrow-band ("channelized") and some wide-band. Gains and maximum output levels also vary. In order to obtain the total gain required for the present application it will usually be necessary to use more than one amplifier. Fig.2 shows some possible simple configurations.

In Fig.2(a) a wide-band amplifier is used in conjunction with a pre-amplifier intended for a

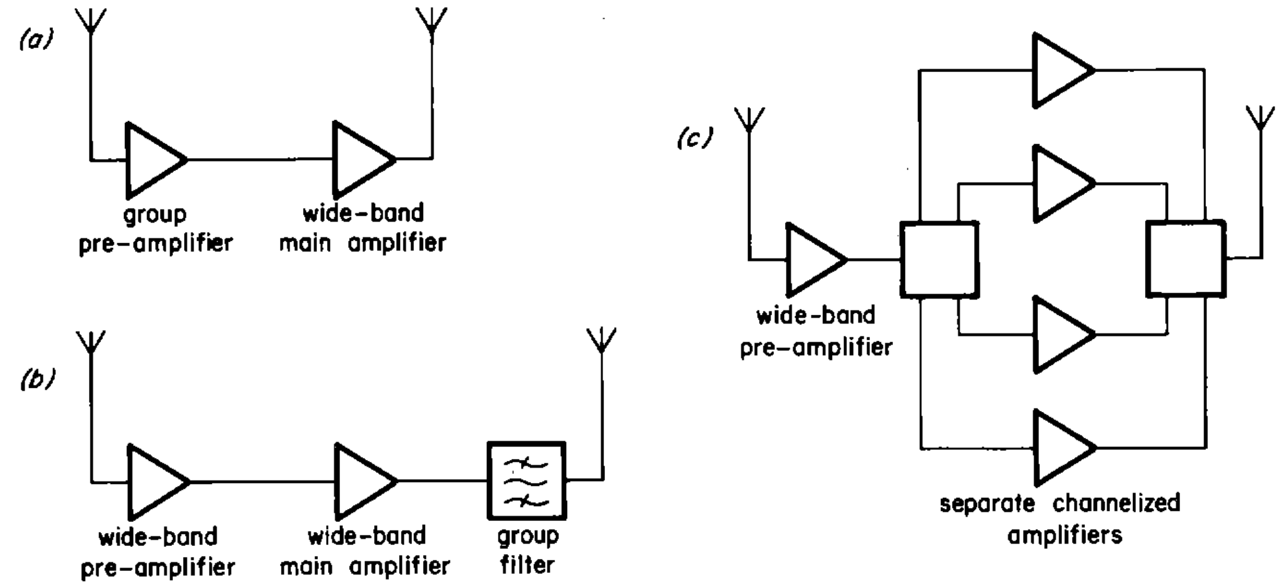

Fig.2 — Amplifier and filter configurations

channel group. This confines the greatest gain to the desired band but the gain of the pre-amplifier falls off only slowly out of band so that a high aerial isolation is needed over a wide bandwidth. The pre-amplifier is best placed close to the receiving aerial.

In Fig.2(b) a group filter has been added and the pre-amplifier may be wide-band. The aerial isolation required is less severe out-of-band. However the filter may have to be a professional type and so relatively expensive. Loss in the filter will reduce the available output.

In Fig.2(c) there are separate amplifiers for each channel. Each amplifier may be a narrow-band ('channelized') type or a wide-band type with frequency-selective splitter/combiners. This arrangement is least dependent on aerial isolation but the cost of the amplifiers is greater. There may also be an advantage in output power.

The maximum output of an amplifier is determined by the generation of intermodulation products (i.p.s.) or cross-modulation products as the amplifier becomes non-linear at high levels. For 4-channel operation the maximum level is determined by cross-modulation between channels, that is the appearance of an unwanted waveform (usually the line synchronizing pulse) on the wanted picture. For commercial amplifiers the maximum output level is usually quoted for a level of cross-modulation of −46dB relative to the wanted signal. When the amplifier is being used for a single channel, the maximum level is determined by the appearance of a 1.57MHz beat resulting from intermodulation between sound carrier and colour subcarrier. The maximum level for a wide-band commercial amplifier is not usually quoted for this condition but may be taken to be 7 dB higher than the four-channel case.[1] Thus the arrangement of Fig.2(c) permits five times the amplifier output of that of Fig.2(a) although the power reaching the aerial is reduced by loss in the combining filter.

The highest output level currently available from a commercial amplifier carrying four channels is 1V peak vision across a 75 ohm load, corresponding to a power level of 13mW peak vision. For single channel operation the maximum power level is 67mW peak vision. The corresponding mean power levels are about 4mW and 20mW respectively. Since these are the maximum permitted levels it may be desirable to derate to allow for propagation variations giving signal enhancement or for any abnormal operating conditions such as low supply voltage. The extent to which this is done will depend on the margins in hand in a particular application. In the limit, it will be preferable to accept a degraded signal for a small proportion of the time rather than to price the station out of consideration.

3.2. Aerials

Domestic television receiving aerials are built to a price for a competitive market and many are not suitable for the present application. The larger aerials have a high wind loading and may not be strong enough for an exposed location. Many aerials are not fitted with a balun transformer, giving rise to currents on the outer surface of the co-axial feeder. It would be difficult to obtain the required isolation for two such aerials whose co-axial feeders ran close together. There are a few types of professional aerials available that are more rugged and are fitted with baluns and these may be used singly or in combination.

There is an unfortunate practice in the industry of claiming aerial gains higher than those achieved, sometimes by as much as 6 dB. Thus the highest gain likely to be achieved with a single aerial is about 15dB relative to a $\lambda/2$ dipole; this may be increased by 2.5 dB for each time the number of such aerials is doubled. This gain, however, will vary over a standard channel group by about 2 dB, being lower for the lower channels.

3.3. Impedance

Commercial amplifiers and distribution equipment are designed for an impedance of 75 ohms, as are receiving aerials. Some professional aerials are available for both 50 and 75 ohms. 50 ohms is normally used at relay stations and the test equipment carried by maintenance teams is for this impedance. It is desirable, therefore, to retain 50 ohms at active deflector link installations. This may result in periodic variations in the amplitude response of the system. If these are too great it will be necessary to fit matching sections at the inputs and/or outputs of the amplifiers.

4. Provision of power for the active deflector.

Some active deflector links will be at sites remote from mains electricity supplies and the cost of bringing in supplies may make the installation impossibly expensive. For such sites it is necessary to look to alternative energy sources. Only the two natural sources of wind and sun will be considered here.

4.1. Requirements

Amplifiers in the arrangements of Fig.2(a) or 2(b) having a total gain in excess of 60 dB and a maximum output of 10mW peak vision will require about 300mA at 24V (7.2W). This will be required typically for about 16 hours per day. A potential economy of up to 30% could be obtained by switching off the amplifiers when there is no signal, but if the consumption of the four receivers that would then be required to detect each channel is allowed for, it would be difficult to effect any saving at all. Thus there is a continuous total power requirement of about 8W for the single amplifier (plus pre-amplifier) of Fig.2(a) and (b) and about 30W for those of Fig.2(c). This clearly militates against the use of single channel amplifiers where there is no mains electricity supply. Further consideration will be restricted to a continuous power requirement of 8W.

4.2. Wind power

There are a number of small wind turbine generators (wind dynamos) either available on the market or currently under development. The requirements for the generator may be summarized as follows:-

(a) The generator should be capable of producing sufficient total power in the wind régime in which it is used.

(b) There should be some mechanism for absorbing excess power, to protect the battery.

(c) There should be some means of preventing overspeeding in high winds.

(d) Maintenance should be minimal.

(e) Capital cost should be low.

There are in general two types of machine — those with an alternator and those with a d.c. generator. The former might be expected to require less maintenance but have a magnetic 'cogging' effect which makes them more difficult to start in light winds. The latter have additional brushes to wear but start very easily. It is common practice to couple the sails directly to the alternator/generator.

Best efficiency is obtained if the turbine produces the required voltage directly. Fortunately 24 volts is one of the most commonly available voltages. With machines producing a maximum output of several hundreds of watts, however, the maximum current will be quite high, necessitating heavy duty wiring.

In practice, where reliance is placed solely on wind power, the maximum output of the machine will need to be of the order of twenty times the mean load. The performance of machines having a maximum output of at least this value can then be

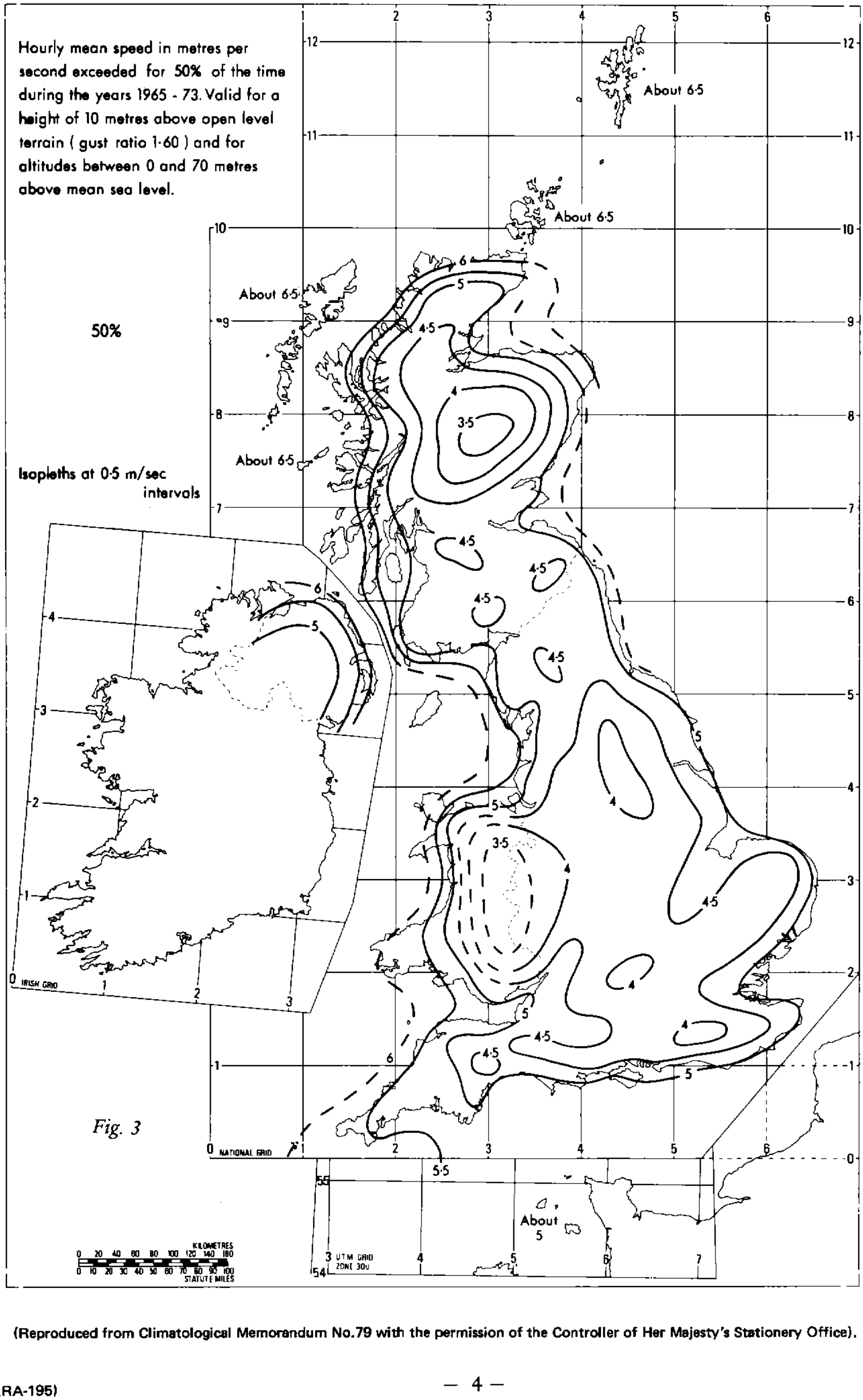

Fig. 3

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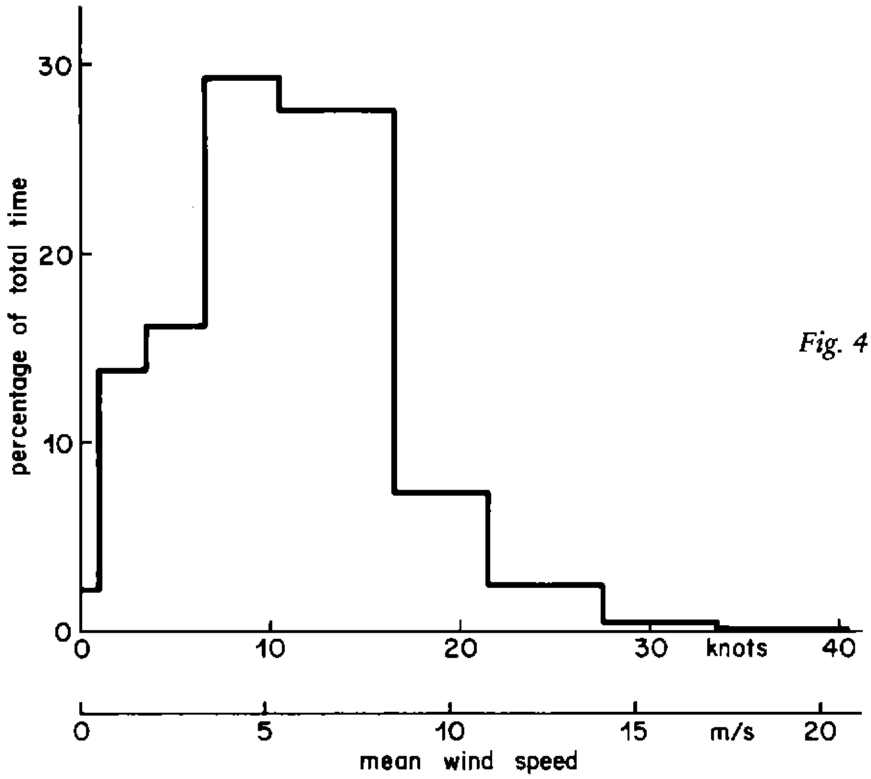


Fig. 4 - Annual distribution of wind speeds at Dunstaffnage (Argyll).

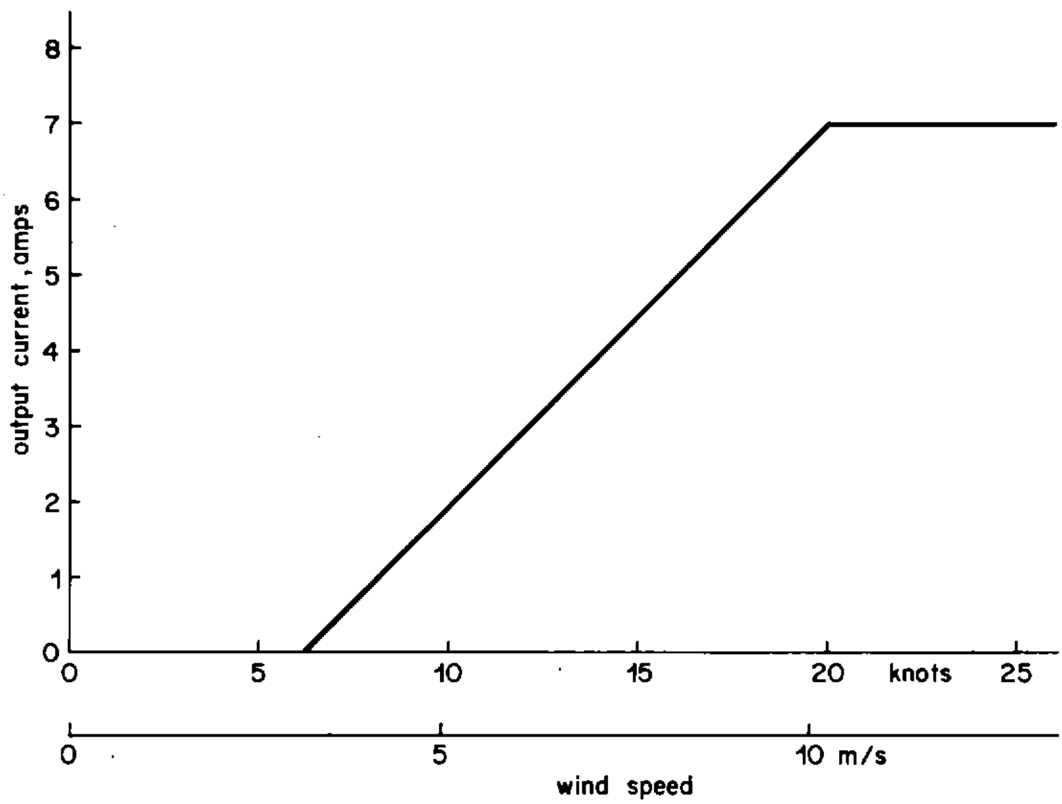


Fig. 5 - Assumed output characteristic of 24 V, 200 W wind turbine.

examined in detail. For applications at present being planned a maximum power output of 160 W is required; the performance of a commercially-available machine of 200 W maximum will therefore be considered.

The first step is to obtain some idea of the wind régime at the site where it is required to operate. The cognoscenti in the use of wind energy[2,3] recommend a survey over a period of time but this is out of the question for a cheap installation. The Meteorological Office publishes data showing, in broad terms, the windiness of different parts of the country[4]; an example is shown in Fig.3. Much more detailed information is available for specific meteorological stations and that for the nearest or most representative station may be used (corrected, if necessary, for height and type of terrain as indicated in References 3 and 4). Fig. 4 shows the measured distribution of wind speeds at a location in the west of Scotland. Assuming that this distribution is valid for a site under consideration, it may be used in conjunction with the output characteristic of the generator to produce the annual average output. Fig.5 shows the idealized output characteristic of the generator for which only the limiting wind speeds are defined. Combining Figs. 4 and 5 gives an annual average output of 2.1 amps.

The above calculation implies a storage battery of sufficient capacity to average out variations over the year. It is more realistic to assess the output available for the worst month. This is found to be August and the corresponding available mean current is 1.2 amps. Even this only relates to an average August so that an allowance must be made for year-to-year variations. This spread is not given in the published data but it is estimated that a monthly average current of half the above (i.e. 600mA) will occur infrequently.

Some of the power generated will be dissipated in wiring and in blocking diodes or rectifier diodes. If the distance between generator and battery is kept to a minimum and low-resistance wiring is used, this loss may be about 10%.

Finally, an allowance must be made for the efficiency of the battery, which is unlikely to be less than 75%. The maximum continuous load that can be sustained is thus found to be 400mA. The safety factor of available load to planned load is then 1.33. It should be noted that no allowance has been made for occasional consumption of power during maintenance, e.g. for lighting or test equipment. If this were required it would be desirable to use a larger generator.

4.3. Solar power

A single solar cell is typically 75 to 100 mm in diameter and has an e.m.f. of about 0.5 V. As the amount of light falling on the cell increases, the e.m.f. quickly reaches the operating level and the internal impedance of the cell falls, allowing power to be extracted from it. In order to operate a 24 V system a module of 72 cells would be operated in series to give a loading characteristic such as that in Fig.6. It may be noted that obstruction of the incident radiation on just one cell will cause a big reduction of the output of the module.

The amount of incident radiation available depends on the geographic location, the season of the year and, of course, the weather. Many terrestrial applications of solar power are in desert or semi-desert regions of the world[5]. Applications in the United Kingdom are possible but need larger solar arrays to catch the limited radiation of these climes.

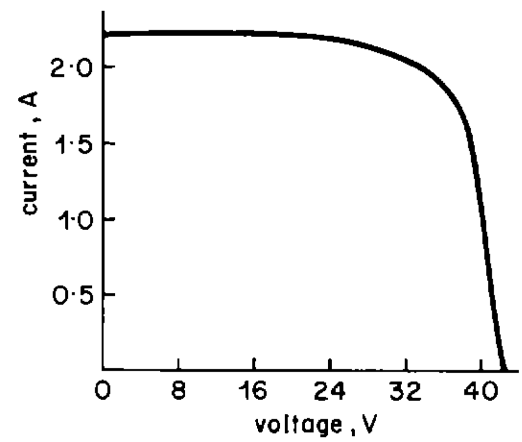


Fig. 6 — Load characteristic of 24 V solar module

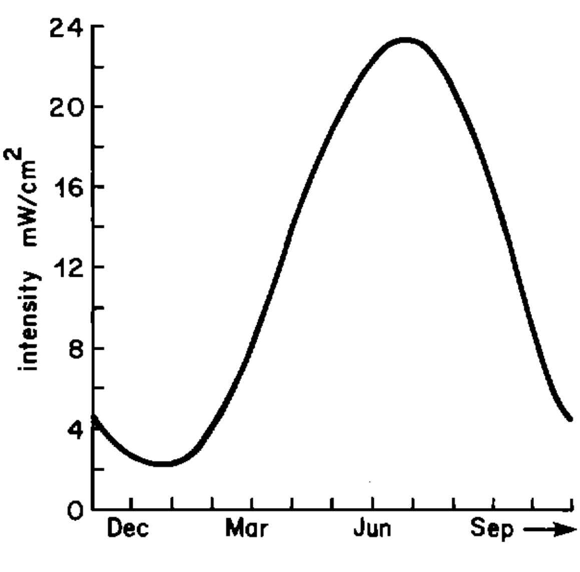


Fig. 7 — Seasonal variation of insolation.

Fig. 7 shows how the insolation, that is the energy falling on unit area of the earth's surface, varies with the seasons; this is a measurement averaged over several years for a latitude of 50°N. [6] It may be seen that in the winter months less than 10% of the maximum insolation is available. A similar result may be deduced from data published by the Meteorological Office.[7]

Fig.8 is a map showing the distribution of the average duration of bright sunshine over the United Kingdom in December (the worst month). It may be seen that in parts of Scotland this is as little as one half hour per day. Fortunately there is some output from a solar cell under 'cloudy-bright' conditions although this is limited too, as the length of day may be only 7 hours.

Thus the parameters of an installation dependant solely on solar power must differ in certain respects from those of a corresponding wind-power installation to suit the availability of the natural energy source. Some energy pick-up can be expected each day but there is a deep seasonal minimum in winter. The battery may be required to make up deficiencies during a worse-than-average winter and so must have a large capacity and a low rate of self discharge.

A solar-power installation to suit an active deflector might consist of 144 cells having a total active area of $1.026m^2$ and connected in a series-parallel arrangement to give an output of 125W for an insolation of $1kW/m^2$. The panels would be set up to face due south and steeply angled (70^o to the horizontal) to get the maximum benefit from the winter sun. This would have the incidental advantage of tending to avoid accumulations of snow and leaves. Such an installation would, on an average winters day, give just about the power consumed.

The big advantage of a solar-powered installation is that maintenance should be minimal, an occasional cleaning of the panel surfaces being all that is needed.

4.4. Choice of battery

The cost of the battery will constitute an appreciable fraction of the capital cost of the station. The battery could also require frequent maintenance. Careful consideration of the requirements and mode of usage is therefore essential.

4.4.1. Type of battery

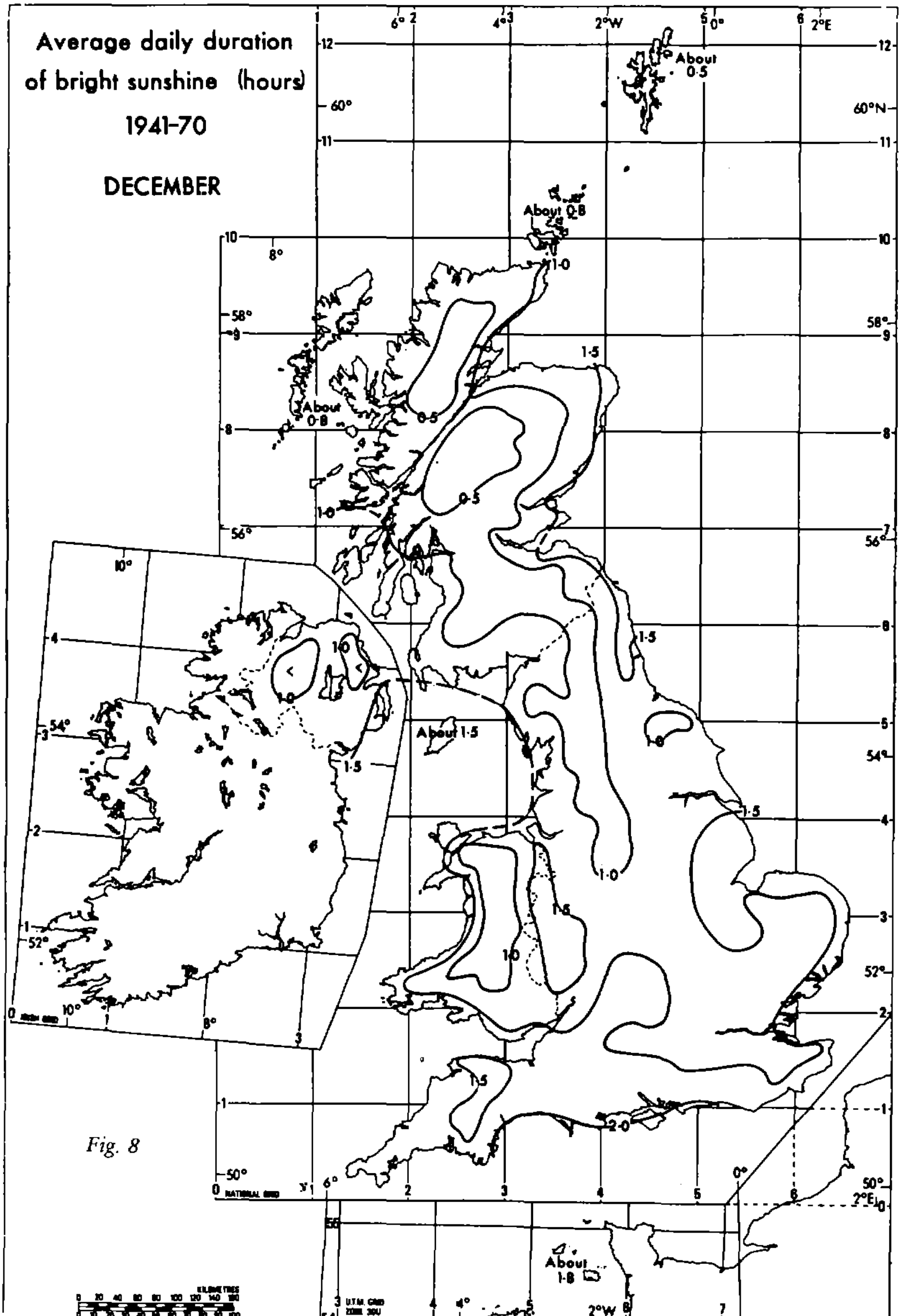
There are two types of re-chargeable battery that are commonly available, nickel-cadmium and lead-acid. The nickel-cadmium battery uses nickel oxide for the positive electrode and cadmium for the negative electrode; the electrolyte is a solution of potassium hydroxide. This type of battery is noted for high-power capability and ruggedness. Other properties of special interest in the present application are tolerance to over-charging, good low-temperature performance, a low rate of self-discharge and long cycle life. Unfortunately a nickel-cadmium battery is significally more expensive than the equivalent lead-acid battery.

The lead-acid battery is the most widely used and extensively developed battery. It uses lead for the negative electrode, lead oxide for the positive electrode and sulphuric acid for the electrolyte. Details of construction vary according to the application. In the Planté cell the negative electrodes are sponge lead (giving a greater effective surface area) while the positive electrodes consist of a paste of lead oxide held in a lead-alloy grid. Such batteries are used to provide reliable standby power for telephone exchanges, etc. They have a long life (20 years or more) but are expensive. They are not designed for regular deep charge cycles.

In the flat plate, pasted plate or Fauré cell, both electrodes are of paste held in a grid. The plates are thin to permit high currents. This is the type used for automobiles. They are cheaper than Planté batteries but are relatively short lived.

In tubular cells the paste is held in tubes of synthetic fibre so that they are less prone to shed active material. They are designed for frequent charge and discharge cycles and so are used for electric trucks as well as certain standby applications; in the latter case the lifetime is quoted as 10 years or more. Cost is intermediate to the first two types.

In addition to the above main types there are other variants. Thus the so-called 'maintenance-free' automobile battery is usually a pasted-plate battery with a large electrolyte reservoir to minimize the need for topping up. There are also sealed cells in which the electrolyte has been immobilized with a gel; these seem to be confined to low values of capacity.



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Thus, in the lead-acid range, the choice would seem to lie between a pasted-plate type, with some means by which the life is extended or the self-discharge reduced, and a tubular type. The self-discharge rate is particularly important for a pure solar installation where the charge must be held for some months. The battery would be made up of units that can be man-handled on site, since mechanized handling will not be available. It must also be remembered that the batteries are to be left unattended at a remote site with a consequent risk of theft. This risk will be all the greater if the battery is made up of an automobile type of popular size and voltage.

4.4.2. Size of battery

The capacity of the battery for a wind-powered installation is deduced from the expected incidence of calm spells. Thus the statistics for Dunstaffnage (Argyll) show that in August winds of less than 7 knots (3.6m/s) occur on average for 47% of the time, or a total of 14.6 days. This is unlikely to occur in one consecutive spell; for example, at Aberdeen, an area of generally lower wind speeds, the maximum recorded continuous period of winds less than 8 m.p.h. (3.6m/s) is 196 hrs. or 8.2. days.[2] It should be safe, therefore, to take 14.6 days as the required period of autonomy, i.e. the period for which the battery can maintain the load, starting from full charge. The capacity of the battery chosen, at the 100 hour rate, is 145 ampere-hours. The rate of self-discharge is said to be less than 3% per week. A fully-charged battery should therefore be able to sustain a load of 0.3 A for 18.6 days. This figure exceeds the required capacity by 27% and so provides a margin for loss or capacity as the battery ages.

The size of battery for a solar-powered installation is determined partly by the area of panels used; to some extent one parameter can be traded off against the other to give the most economic mix. At present, solar panels are fairly expensive and so a fairly large battery will be appropriate. The battery to be used with the solar panel detailed in Section 4.3. will have a capacity of 290 ampere-hours to give a period of autonomy of 36 days. It is desirable that it should be of a type having a low rate of self-discharge and a high efficiency.

4.4.3. Charge regulators

Wind and sun are very variable energy sources and systems using them have to be designed for the likely minimum output. For much of the time, then, the system will have a surplus of energy that needs to be diverted from the battery to protect it from damage through overcharge.

The charging cycle of a lead-acid cell is shown in Fig.9. Two features may be noted: the cell voltage rises markedly towards the end of the charge and gassing* takes place when the cell voltage rises above 2.35 volts. The rise in cell voltage may be used to control the charge. Perhaps the simplest system is to use a constant voltage charger so that the charging current automatically ceases when the battery voltage reaches a predermined value. A voltage regulator could be put in series with a solar panel to achieve this result. It would not, however, be satisfactory with a wind dynamo; the voltage drop in the regulator would reduce efficiency at low wind speeds and the dynamo would not be kept on load at high wind speeds when the battery was fully charged. A better arrangement is to divert the excess power into a dummy load when the battery voltage passes a predetermined level. This can be done by switching but it is better to divert the power progressively and to retain a small charging current. Fig. 10 shows the circuit of such a regulator and Fig. 11 shows how the current is divided between the battery and regulator as the battery voltage rises. The voltage at which the regulator operates is chosen to avoid excessive loss of electrolyte through gassing. At the same time a little gassing is desirable in order to prevent stratification of the electrolyte, that is the formation of layers of different specific gravities.

4.5. Hybrid arrangements

The design of both wind-powered and solar-powered installations is based on the performance obtained during the worst month of the year.

For wind that month is August, for sun it is December. Thus a combination of the two systems will give a more uniform power output taken over the whole year and should therefore permit a reduction in the required battery storage. If both systems were available in an infinite range of sizes, then the combination requiring the smallest size of battery would be the natural one to use. However, suitable wind turbine generators are available in very few sizes so that the problem becomes one of matching up particular units. The addition of a solar panel might permit the use of a wind turbine that was otherwise just too small. There are other

*the generation of bubbles of hydrogen and oxygen at the plates.

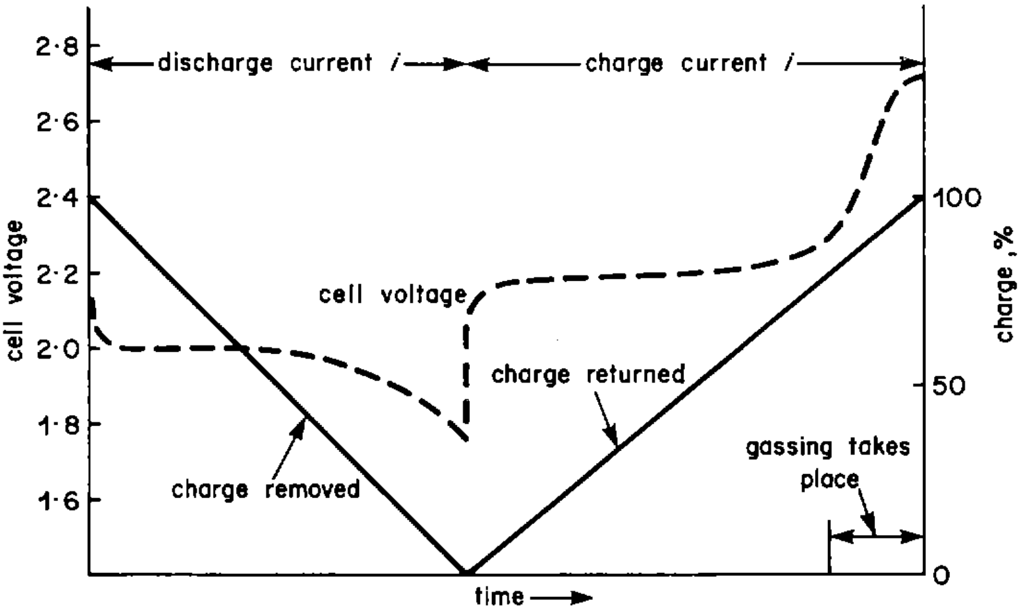

Fig. 9 - Charging cycle for a lead-acid cell

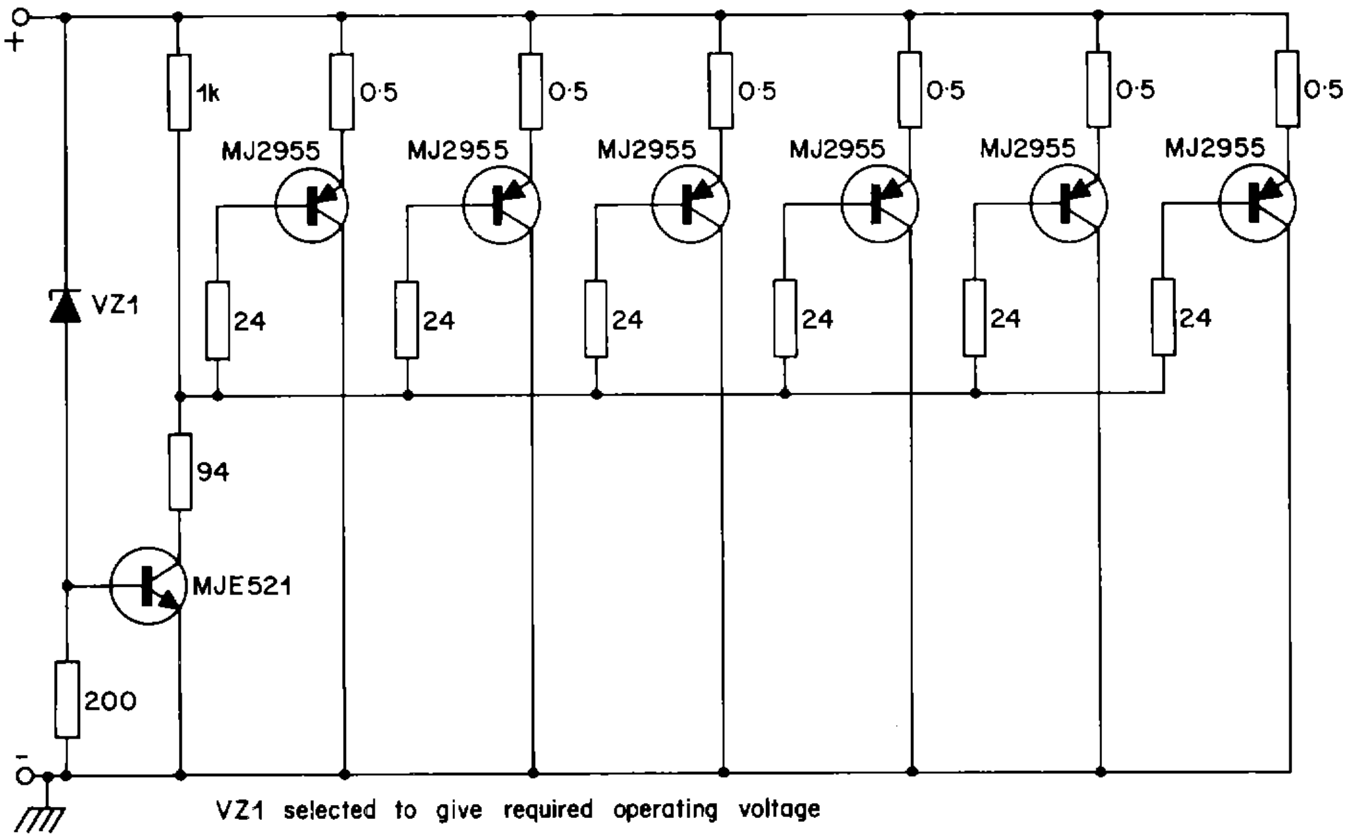

Fig. 10 — Shunt voltage regulator circuit

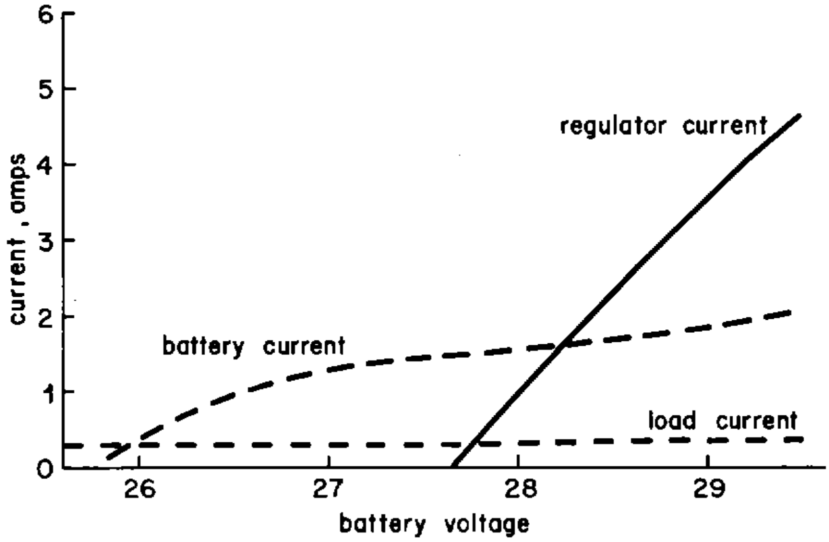

Fig. 11 – Apportionment of current from 200 W wind turbine

considerations besides capital cost and perhaps the most important of these is maintenance, especially at remote sites. The addition of a solar panel to a wind turbine generator might be the best way of providing a margin of safety without a large increase of capital cost.

5. Self-help Schemes

Some small communities, mostly with populations of 200 or less, will not get a relay station provided by the broadcasters. However, if they so wish, they may be licensed to build their own station. Such installations will usually be of the type described in Section 3, with some differences. The receiving and transmitting aerials will tend to be mounted on separate wooden poles spaced 5 to 10 m in order to achieve the necessary aerial isolation. Feeders will usually be one of the low-loss 75 ohm impedance types that are available commercially. Aerials will be of the high-gain domestic type for cheapness. Where the community to be served is compact there should be no particular difficulty in arranging aerials but a range exceeding 2 km will rarely be achieved. A particular difficulty will arise if the houses to be served subtend a substantial angle or if there are several isolated groups. It will rarely be satisfactory to deploy several aerials in different directions since they tend to interact.

6. Conclusions

The technical requirements affecting the use of active deflector installations to bring a programme feed to a u.h.f. relay station have been defined. The range of such stations is limited by the rather low output of the commercially available amplifiers. Nevertheless it would appear that there is a definite, if limited, application for such stations. Successful field trials have been made in two locations and the first full installation is planned to go into service in Western Scotland in 1981. The equipment specifications for this installation are based on the technical requirements given in the Report.

Some active deflector installations will be remote from public electricity supplies and so require alternative energy sources. Both wind and solar systems appear viable in the U.K. but there is as yet little practical experience on the operation of either. It is proposed to ensure continuity of operation by providing a combined system for the first installation.

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